RM@Schools: Fostering Students' Interest in Raw Materials and a Sustainable Society

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Abstract

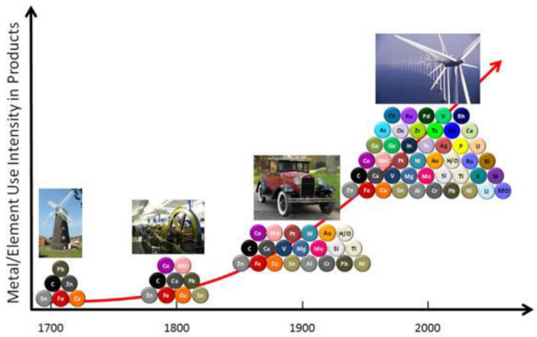
Raw materials (RMs) are essential for the production of a broad range of goods and applications used in everyday life. In particular, the accelerating technological innovation and the rapid growth of emerging economies have led to a steadily increasing demand for a great numbers of metals and minerals. They are crucial also for fostering the transition towards a low-carbon economy.
Thanks to a strategic European Partnership some learning paths for pupils aged 10 to 18 years were developed in the framework of Raw Matters Ambassadors at Schools (RM@Schools), a European project funded by the European Institute for Innovation and Technology (EIT) since 2016. These paths aim at increasing the understanding of how RMs are needed in modern society, and to make careers in RM more attractive. The RM@Schools learning integrated method enables the students to expand their background knowledge in this field outside the current curricular topics and allow interconnections with others subjects of study.
Several educational approaches (i.e., learning-by-doing, team working, peer-to-peer, gamification, etc.) are used to foster students' interest in science and technology, in particular in circular economy and RM-related topics. Young people are trained to become science communicators (Young RM Ambassadors), and to create a "product" that can be communicated outside of the class. This method helps students to develop skills such as creativity, critical thinking, awareness of responsibility and teamwork, as well as to improve scientific knowledge on some scientific topics.
The learning pathway covering the whole RMs value chain, from geology to electronic waste management, has a modular structure: (1) Lesson - introducing the students to relevant content knowledge; (2) Activity – experiments with RM-related hand-on kits; (3) Visit – to industry or research centers; (4) Create/Communicate – students are asked to communicate by creating a product designed to promote dialogue on a key message they have learnt; (5) Society – students are engaged in public events, such as science fairs, as well as in presenting their best dissemination products during an annual European Conference.

Keywords: *Raw materials, sustainability, secondary school, cross-curricular learning, lab experiments, communication*

1. Introduction

In human history, every technological progress has involved the use of increasingly larger quantities and varieties of raw materials (Fig.1). The last leap occurred at the end of the last millennium with the introduction of new forms of renewable energy and with the miniaturization of electronic circuits. Many of our current technologies (mobile phones, computers, automobiles), and sources of renewable green energy (solar and wind) have become more and more reliant on metals (i.e., rare-earth-elements, indium, etc.).

Fig.1. As technology advances, so too does the need for elements found within the earth's crust.

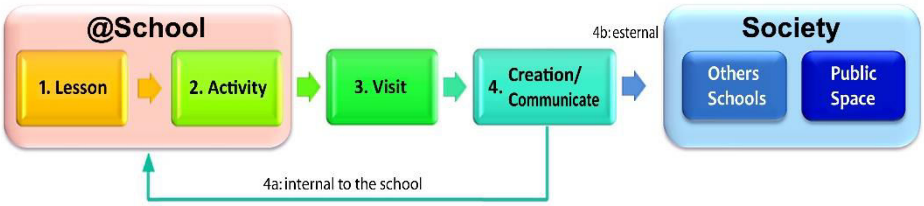


Supply problems or limited availability of these RMs can prevent the development and dissemination of renewable energy projects to address issues like climate change and transition to a low-carbon economy. The criticality of a particular material for European economy is assessed on the basis of the combination of two factors: economic importance and supply risk. Critical raw materials (CRMs) are essential for high tech products and breakthrough technologies. For example, a smartphone might contain up to 50 different metals, all of which providing different properties such as light weight and user-friendly small size.
The prospect of doubling the global resources use by 2030, the priorities are to address raw materials through the entire value chain (sourcing, use and recycling) and to foster a change of mindset in young people.
To trigger the students' interest in raw materials and a sustainable society, several learning paths for pupils aged 10 to 18 years were developed in the framework of Raw Matters Ambassadors at Schools (RM@Schools), an European project funded by the European Institute for Innovation and Technology (EIT), the largest consortium in the raw materials sector worldwide. RM@Schools was established in 2016 and became the flagship project in the Wider Society Learning segment of the EIT RawMaterials in 2018 (http://rmschools.isof.cnr.it/). It is led by National Research Council of Italy (CNR) in collaboration with partners across Europe, and it engages industry, research and education to advance knowledge on raw materials in Europe.
Different educational approaches are used to foster students' interest in science and technology, in particular in circular economy and RM-related topics.
An active learning approach is encouraged by involving students in experiments using raw material-related hands-on educational toolkits and in communication actions, but a core element of the RM@Schools approach is to empower students to communicate with peers and wider society about critical concepts related to raw materials and their use.
Teachers can approach many topics within their curriculum using the concept of critical raw materials as a springboard. The topic of raw materials can be investigated from a science and technology perspective, but it can also be studied from a socio-political or economic viewpoint.
Raw materials is a great topic for students to investigate politics, policy, consumerism, and the interaction between economics, politics and product use and development.
Education and awareness of the uses of raw materials can lead to changes in governance as the values and the voice of citizens are listened to. We hope that students will become more responsible and active citizens when they have gained a better understanding of these complex issues.

2. RM@Schools Learning Paths

RM@Schools has developed learning pathways (Figure 2) where different educational approaches (such as learning-by-doing, team working, peer-to-peer, gamification, etc.) are used to generate and foster students' interest in science and technology. The learning paths are oriented toward the common goal of guiding students to create a "product" to be communicated outside of the class. By doing this, students develop 21st century learning skills such as creativity, initiative, critical thinking, awareness of responsibility and teamwork, in line with the *Entrepreneurial Skills Pass document* [1]. With the end goal of creating a communication tool targeting an external audience, students are actively involved in the learning process. Students benefit from such an approach more widely as the skills involved are increasingly viewed as important skills in the workplace. Many jobs now require creative thinking and communication skills, including positions in the world of business and science. People usually think that creativity is an inbuilt talent, but it is not entirely so. As with any skills, creativity can be nurtured in the classroom with simple strategies and practices that trigger creative thinking and provide opportunities for communicative action. Ideas generate new ideas.

Fig. 2. The main steps of the RM@Schools learning pathway.



The steps of the RM@Schools learning pathway (Fig. 2) tie in with various pedagogical practices [2-4] as follows:

1. Lesson – It begins by introducing the students to the relevant knowledge to understand the topic. This can be done starting with a frontal lesson provided by the teacher or a guest speaker or by working with resources (active-learning), followed-up by a lesson. It should also involve a sharing of the personal experiences of the students on the lesson's topic and a final discussion. This can be accomplished by using triggers, such as the smartphone example shown earlier.

2. Activity - Students are then engaged in a practical activity - laboratory experiments, serious games, etc. - to support or extend their learning.

3. Visit - After the activity, students can also visit a place that is relevant to the lesson, so they can experience its impact in the real world.

4. Create/Communicate – Afterwards, the students are asked to communicate what they have learnt through the creation of a product designed to promote dialogue around a key message. This element has two major parts: (a) Create and (b) Communicate. The teacher during this phase can use a guided- or a student-centred approach. Different educational approaches such as teamwork, peer-to-peer learning, cooperative learning, and gamification can be used in order to foster creative thinking. Once students have developed a product (i.e., video, comic, poster, lab activity, etc.), they are expected to share it within their school and then in a larger community (Fig.3).

5. Society – Students engagement with society can be done through participation in public events such as science fairs and festivals. Students can also choose to further engage with society through raising public awareness or taking social action.

Fig. 3. Development of a dissemination product by a high school class in Italy

3. RM@School Hands-on Toolkits

An active learning approach is encouraged by involving students in experiments using raw material-related hands-on educational toolkits and in communication actions. These toolkits have been developed by the consortium's experts, in some cases in collaboration with schools where students have developed the lab activities as part of their practical communication action targeting their peers and society around them [5]. In Table 1 some activities available on the recycling topic are summarised.

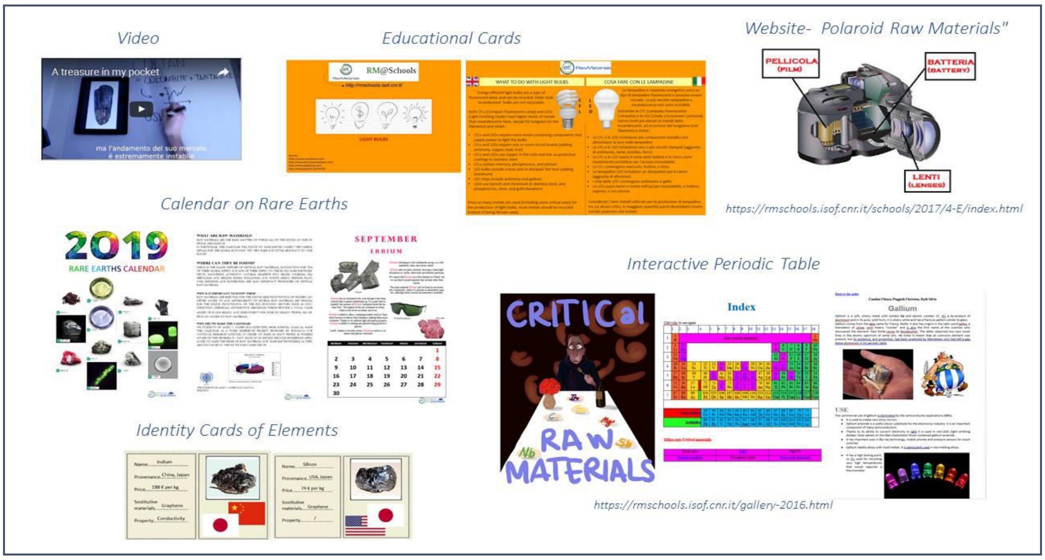
Table 1. Toolkits available under the theme: Recycling

Toolkit	Age	Learning objectives	Content	Subject links
The Recycling Goose Game	8-13	Students gain a deeper understanding of what can and can't be recycled, household waste segregation and recycling	Large-scale game with board pieces and cards provided for printing.	Environment, recycling, materials, active citizenship
Let's make recycling blue	14-19	Students learn chemistry skills and separation techniques.	A two-phase experiment which begins with the precipitation of Prussian blue pigment and then the filtering of metals using this pigment	Chemistry; precipitation, chelation, chemical reactions
Separation of copper and iron - two approaches	16-19	Students reinforce their understanding of solubility, and develop skills in reaction equations and qualitative analysis	Two separate experiments using two techniques. Good background info, clear description ofwhat is happening, recipes for solutions provided. Questions and answers on procedure and reactions included.	Chemistry: precipitation & leaching, acids and bases, cation, anion
RM & HDD	14-19	Students learn how to make educational cards, practice collaboration, and design thinking	1. Lecture on neodymium in Hard Disc Drive (HDD). 2. Multimedia materials to learn how an HDD works, and how to recover neodymium from an HDD.	Technology, economics, media
Recycling of silicon based PV modules	14-19	Students learn about the importance of photovoltaic (PV) waste recycling processes in the circular economy world	Lab activity: assembling and disassembling a PV mini-panel	Technology, energy saving
Copper: how to recover copper from electrical circuits	14-19	Students learn the fundamental role of the metal recycle and develop skills in reaction equations	An inquiry-oriented activity and 1 lab activity module to show how to recover copper from electrical circuits 1 communication activity is suggested together with evaluation grids.	Chemistry, recycling, technology
The rare earth elements wheel	10-15	Students learn about the metal content, in term of rare earth elements, in Electric Electronic Equipment (EEE) and Waste EEE (WEEE)	One lesson on The jungle of WEEE, an exercise section about the treatment of WEEE, and an educational game	Recycling, metal proprieties and applications, environment
Zinc electro – winning - From ore/scrap to target metal	16-19	Students learn about mining and recycling, economic and social issues and less CO_2 emissions by recycling zinc	Lab activity consisting of a model experiment to understand the process chains in mining and recycling	Oxidation and reduction processes, electrochemistry, economy, social issues

4. Science communication by students

Encouraging students to communicate within their class and to other audiences is a key part of their learning. In order to improve transversal competences (i.e., critical and creative thinking, collaboration, etc.) and promote inclusion of all individuals - all talents necessary in science learning - students are asked to become societal Ambassadors by creating dissemination, by giving discursive argumentation with "peers" ("talking science") and participating to public events as active players (Fig. 3). Good examples of communication products and experiments developed by students (step 4 of the RM@Schools learning pathways – Fig. 2) can be found on the RM@Schools website under 'gallery' (Fig. 4)

Fig. 4. Communication products of different typologies realised by pupils.



Project's European Conference that takes place annually in Bologna plays pivotal role in teaching science communication. It is not only a very important celebration of work done by students but it also gives young people the opportunity to meet their peers from the other countries and explain by themselves on the stage what they have created in the framework of the project.

5. Cross-curricular Links

Teachers can cover many topics within their curriculum using the concept of critical raw materials as a springboard. The RMs topic can be investigated from a science and technology perspective but can also be considered from a socio-political or economic viewpoint. It is a truly transversal topic and students can delve into the complexities of raw material use, through problem-based learning; addressing many societal aspects, and searching for solutions in a complex system. Raw materials is a great topic for students to investigate politics, policy, consumerism and the interaction between economics, politics and product use and development.
Subjects where RMs or critical RMs are relevant: Ecology/Environment; Biology; Chemistry; Geography; Physics; Technology; Social Sciences; Economics/Economy; Ethics/Philosophy/Religion; Media Studies; Politics

6. Conclusions

Education and awareness of the RMs uses can lead to changes in governance as the values and voice of citizens are heard. By gaining a better understanding of these complex issues, we hope that students will become responsible and active citizens. Thus, the RM@Schools methodology could be helpful in changing societal perceptions of RMs from "indifference" to "involvement and responsibility" as well as for ensuring a next generation of well educated, innovative and multidisciplinary experts so much needed in XXI century industry.

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